Conceptual Design of an Oxygen Diffuser System to Reduce Anoxic Products in Reservoir Releases

Mark H. Mobley, Mobley Engineering, Inc.

R. Jim Ruane, Reservoir Environmental Management, Inc.

For Presentation at:
Impacts of Hydrogen Sulfide at Reservoirs, Dams, and Tailwaters Workshop

Dates: July 30 and 31

Location: Nashville, TN

Introduction

This abstract is a summary of the diffuser design portions of a study conducted by the authors for the Nashville District of the US Army Corps of Engineers for J. Percy Priest Dam and reservoir. Design goals for the diffuser system included increasing tailwater DO levels and reducing anoxic products such as hydrogen sulfide.

Diffuser Design Requirements

Unlike previous porous hose diffuser applications, the high oxygen demands, mid-level intakes, and long periods of no turbine operation at J. Percy Priest require a significant departure from a straightforward hydropower oxygenation design. The conditions at J. Percy Priest require an oxygenation system that is capable of meeting the oxygen demands of high water flow rates during consecutive days of turbine operation, as well as maintaining oxygenated forebay conditions during long periods of no turbine operation. In addition, the system must distribute the oxygen well upstream of the dam to obtain the retention times necessary to impact the anoxic products in the reservoir. The conceptual design of the oxygenation system in this presentation is the result of the application of the expertise obtained designing, installing and operating eleven line diffuser systems for TVA and other utilities.

Diffuser Design to Meet Objectives

To meet these objectives, the design team took advantage of the inherent flexibility of the porous hose line diffuser to place oxygen at specific locations spread throughout the J. Percy Priest forebay to meet specific oxygen demands identified by the team. The diffusers are designed to serve dual purposes by being operated to meet different oxygen demand rates depending on turbine operation. During turbine operation, oxygen input is spread over the elevations of the turbine withdrawal zone up to 5,000 feet upstream of the dam. An oxygen input of 37 tons per day is required to increase the 4,600 cfs turbine flow from 2 to 5 mg/L. However, just achieving 5 mg/L is not sufficient to avoid an immediate DO decrease in the tailwater due to oxygen demands still active in the turbine release. Therefore, additional diffusers are located in the old riverbed and at higher elevations to satisfy the maximum BOD expected for the incoming water from the non-oxygenated portions of the reservoir. During periods of no turbine operation, three of these same diffusers would be operated at reduced oxygen flow rates to place oxygen in strategic elevations of the forebay and directly in front of the turbines to maintain an oxygenated volume for initial turbine operations. Longer periods of no turbine operation will afford these diffusers the retention time necessary to oxidize more anoxic products in the forebay.

In this conceptual study, the line diffuser system is supplied by a liquid oxygen storage facility. The oxygen facility was designed with 80 tons per day of delivery capacity and would be located on the J. Percy Priest Reservation near an existing boat ramp. The use of liquid oxygen is the preferred method for supplying J. Percy Priest because liquid oxygen deliveries are readily available and the facility is economical, highly reliable and simple to adjust and operate.

Conceptual Design of an Oxygen Diffuser System to Reduce Anoxic Products in Reservoir Releases

Mark Mobley, Mobley Engineering, Inc., Norris TN
R. Jim Ruane, Reservoir Environmental Management, Inc., Chattanooga, TN

For Presentation at:
Impacts of Hydrogen Sulfide at Reservoirs, Dams, and Tailwaters Workshop
July 30 and 31
Nashville, TN

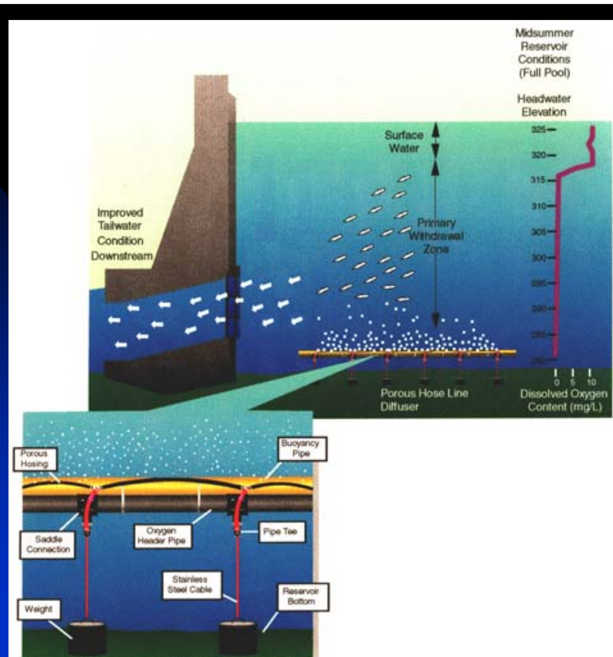
Introduction:

- The US Army Corp of Engineers, Nashville District's J.Percy Priest hydropower project exhibits water quality problems each summer.
- A conceptual oxygen diffuser design to improve water quality conditions was completed in 2000.
- Objectives for the design included:
  - Meet the 5 mg/L State DO standard in the turbine discharge
  - Reduce the release of dissolved iron and manganese
  - Eliminate the hydrogen sulfide odor

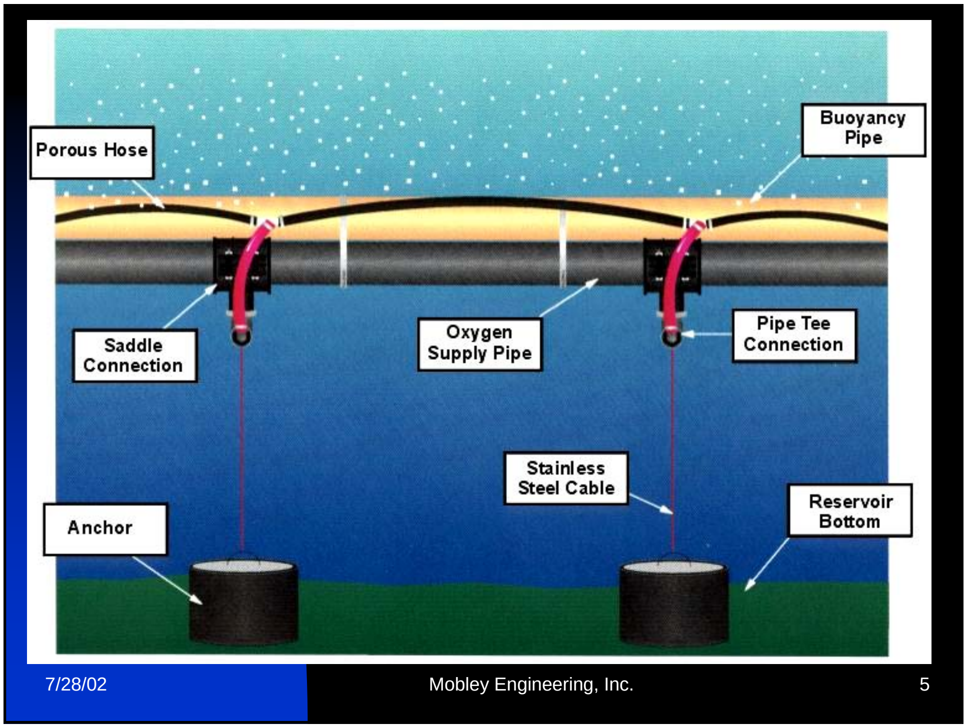
Line Diffuser:

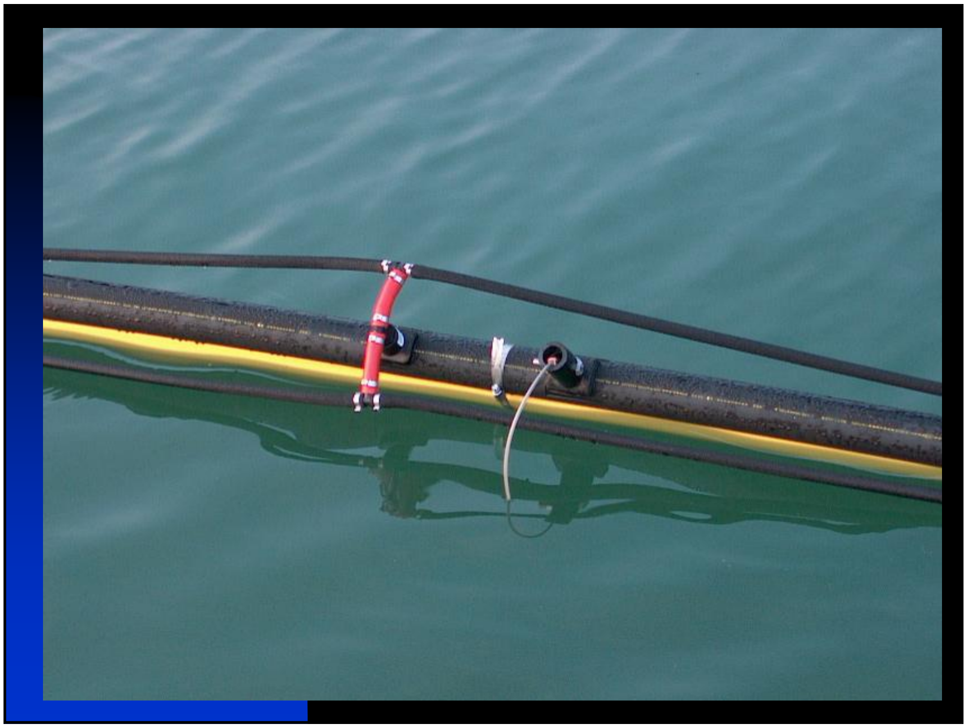
- The Line Diffuser places oxygen in the reservoir to achieve optimized DO enhancement of hydropower releases:
  - Diffusers are located on the reservoir bottom usually along the old riverbed.
  - Oxygen bubbles are spread over a large area to obtain high oxygen transfer efficiencies.
  - Operation of the diffusers can be timed with hydro turbine operation or spread over a sufficient volume to meet peaking demands.
  - Anoxic products can be reduced in the reservoir releases.

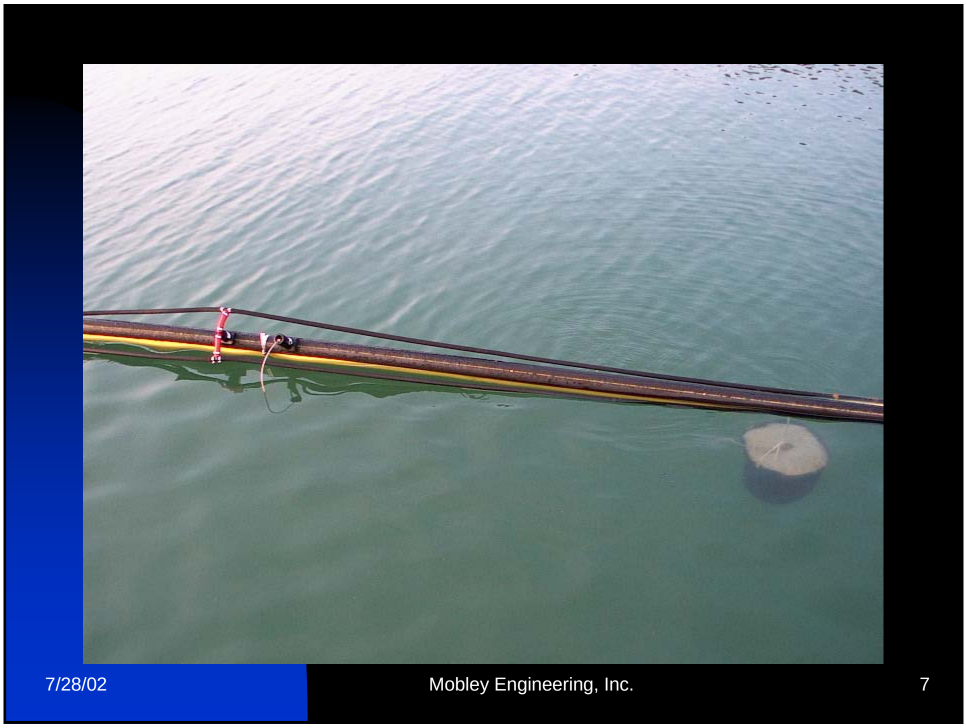
7/28/02 Mobley Engineering, Inc. 3

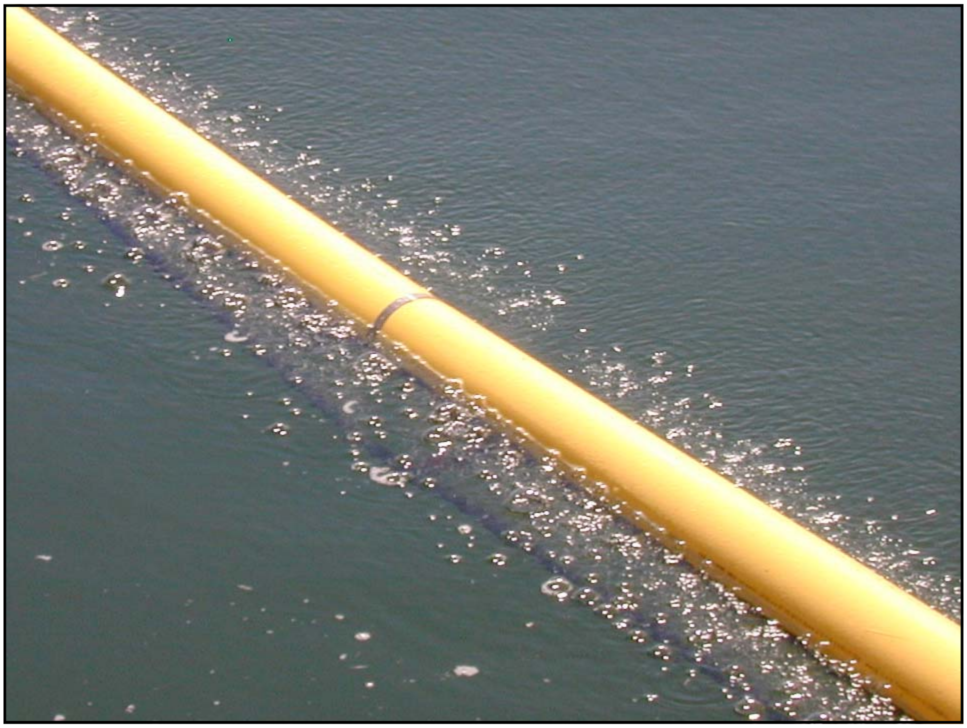


7/28/02 Mobley Engineering, Inc. 4


Porous Hose
Buoyancy Pipe
Saddle Connection
Oxygen Supply Pipe
Pipe Tee Connection
Stainless Steel Cable
Reservoir Bottom
Anchor
7/28/02
Mobley Engineering, Inc.
5

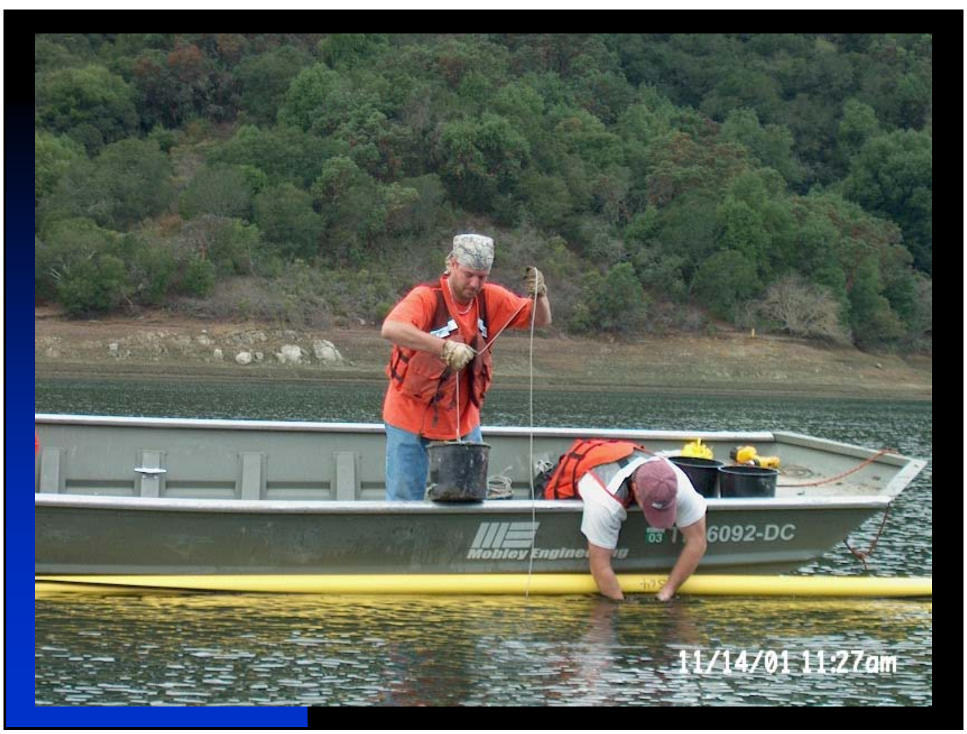


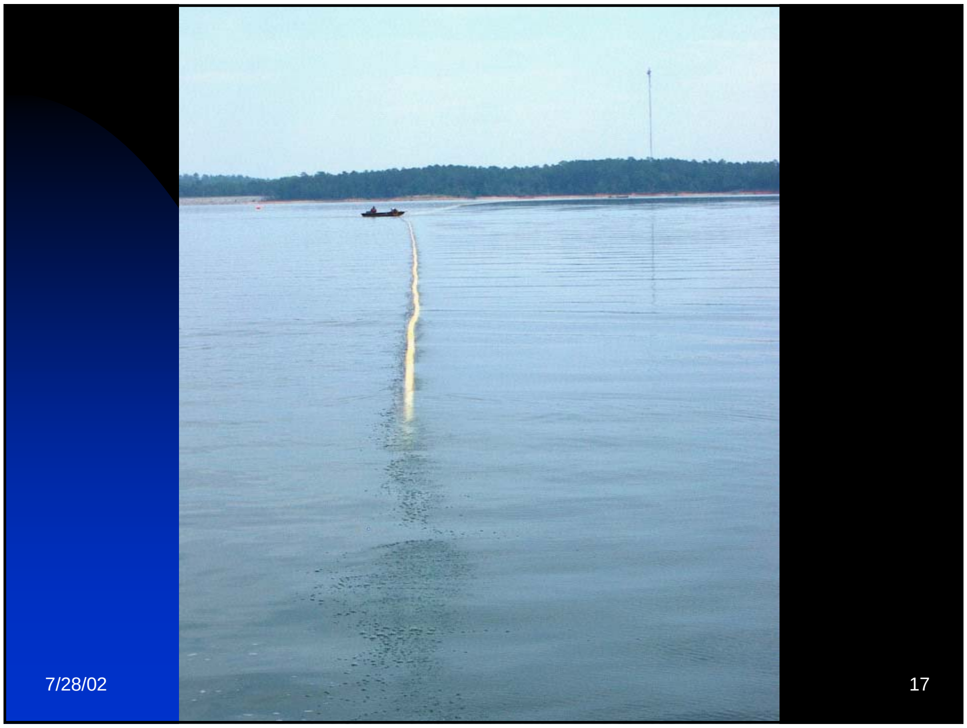

7/28/02
Mobley Engineering, Inc.
7



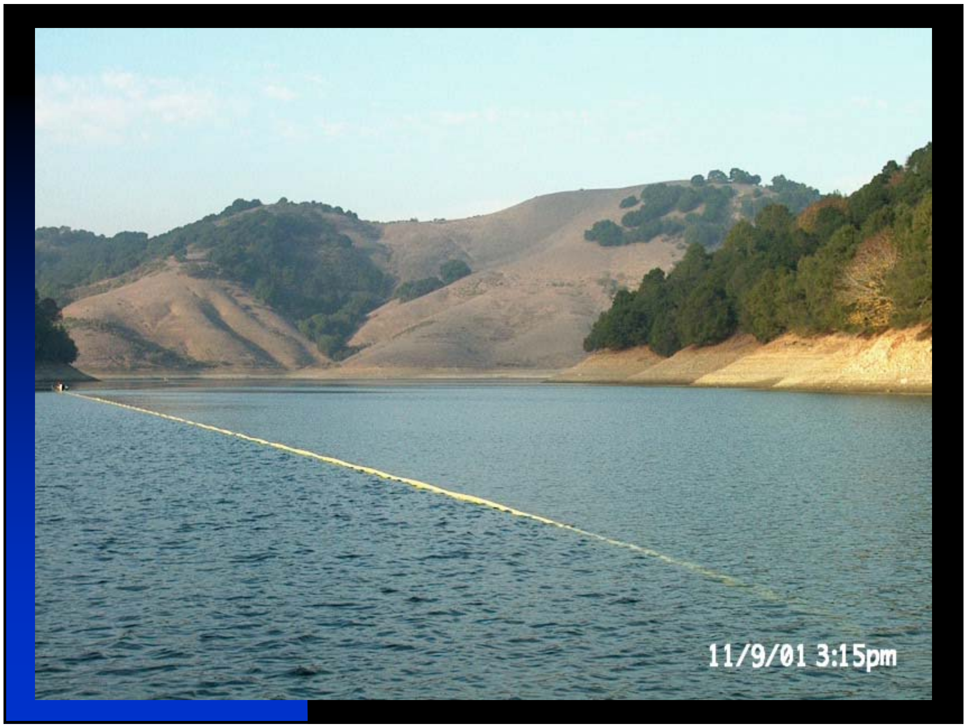

10/31/01 8:20am

7/28/02 Mobley Engineering, Inc. 12

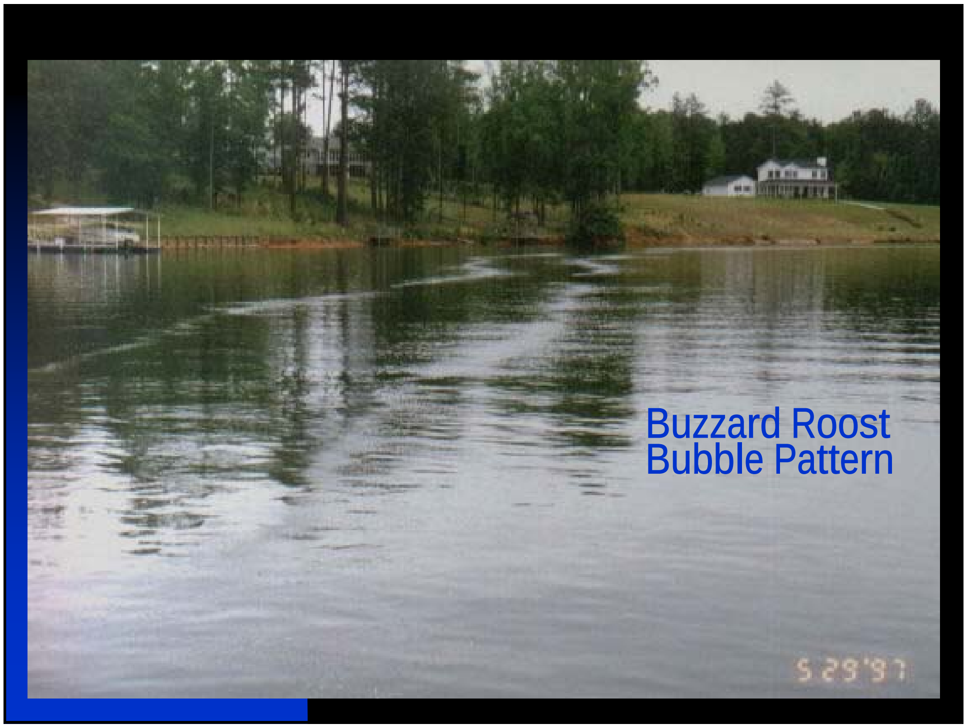

6092-DC
11/14/01 11:27am


7/28/02
17


7/28/02
Mobley Engineering, Inc.
18


11/9/01 3:15pm


7/28/02
Mobley Engineering, Inc.
20


Buzzard Roost
Bubble Pattern


30
60
90
120
150
Nearest
ZOUT
PAGES
MENU
7/28/02
Mobley Engineering, Inc.
22

Oxygen Supply

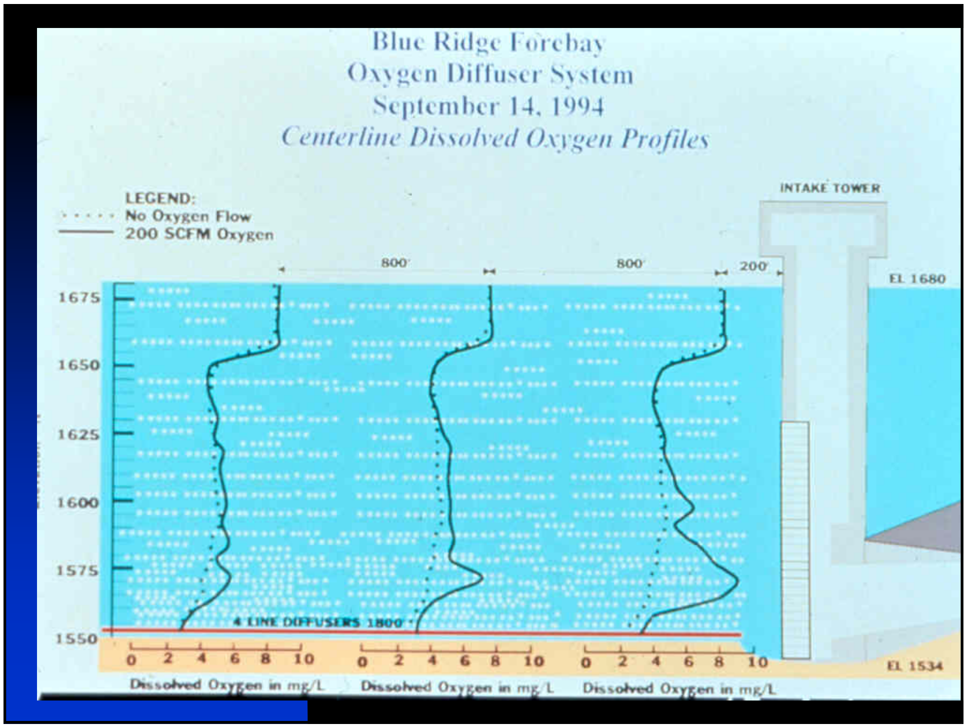
- Line diffusers are typically supplied with oxygen for hydro power applications
- Liquid oxygen is trucked to onsite storage tank
- Vaporization from liquid to gas provides pressure to move gas through the diffusers

7/28/02 Mobley Engineering, Inc. 23

Application to J. Percy Priest

- Oxygen input of the diffusers was sized to provide:
  - 3 mg/L increase in turbine flow
  - Satisfaction of the oxygen demands exerted during turbine operations
  - Maintenance of the oxygenated forebay volume during non-turbine operation periods

7/28/02 Mobley Engineering, Inc. 24



Forebay Retention Times During Turbine Operation

Retention Time (days) 4600 cfs

Elevation	8000	7000	6000	5000	4000	3000	2000	1000
490	12.4	10.9	9.2	7.9	6.7	4.7	2.6	1.3
480								
470	2.3	2.0	1.6	1.4	1.2	0.8	0.5	0.3
460								
450								
440	2.6	2.2	1.9	1.5	1.2	0.6	0.4	0.3
430								
420	3.7	2.7	2.5	2.1	1.3	0.8	0.6	0.3
410								
400								
390								
380								

Distance Upstream of the Dam

7/28/02 Mobley Engineering, Inc. 26

Forebay Retention Times During Non-Turbine Operation

Retention Time (days)
August - September Average Daily Flow (315 cfs)

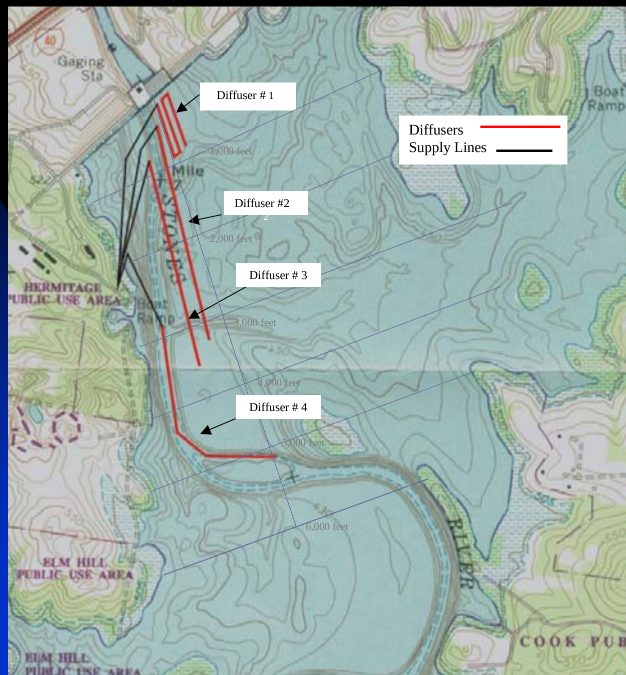
Elevation	8000	7000	6000	5000	4000	3000	2000	1000
490	181.6	158.7	134.0	115.9	97.8	68.4	37.7	19.3
480								
470	33.7	28.9	24.0	20.2	17.0	11.1	6.7	3.8
460								
450								
440	38.1	32.0	27.4	21.6	16.9	9.3	6.5	3.7
430								
420	53.7	39.5	36.9	30.3	18.4	12.2	8.5	3.8
410								
400								
390								
380								

Distance Upstream of the Dam

Diffuser Design Flows

J. Percy Priest Flow Rates

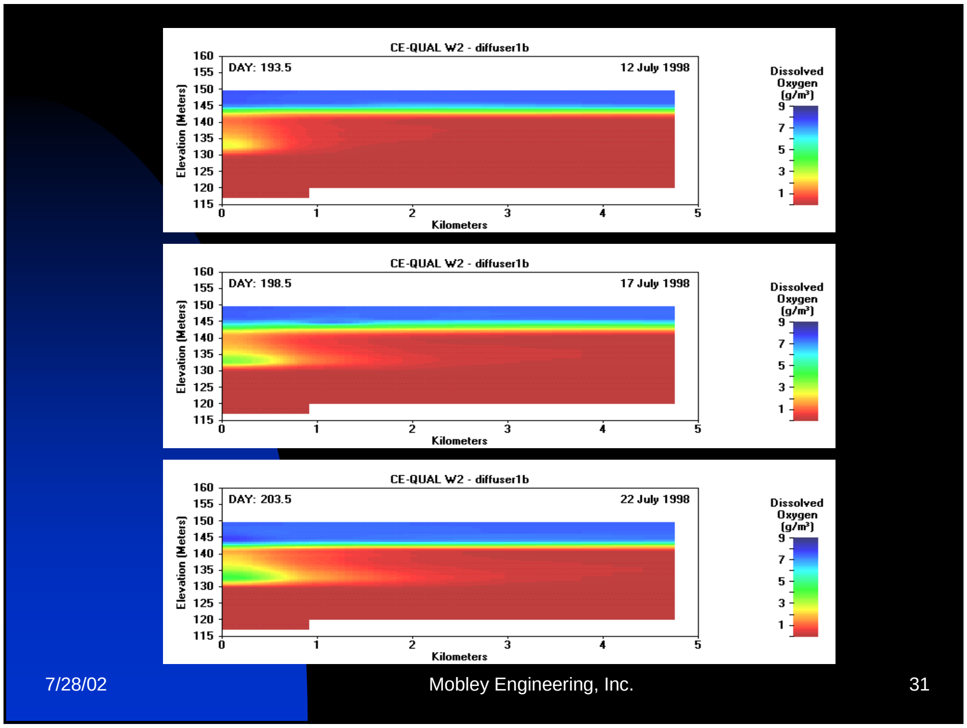
		TURBINE ON				TURBINE OFF					
	Length	**Turbine**		**Turbine Make-up**		**Turbine Maintenance**		**Forebay Maintenance**		**Forebay Make-up**	
	(feet)	O2 Flow (scfm)	Flux (scfm/ft)	O2 Flow (scfm)	Flux (scfm/ft)	O2 Flow (scfm)	Flux (scfm/ft)	O2 Flow (scfm)	Flux (scfm/ft)	O2 Flow (scfm)	Flux (scfm/ft)
#1	**2,500**	260	0.12			17	negl				
#2	**2,500**	260	0.12								
#3	**2,850**			300	0.12			27	negl	4.7	negl
#4	**3,150**	260	0.12	63	0.12			16.5		1.4	
Total	**11,000**	780		363		17		27		4.7	

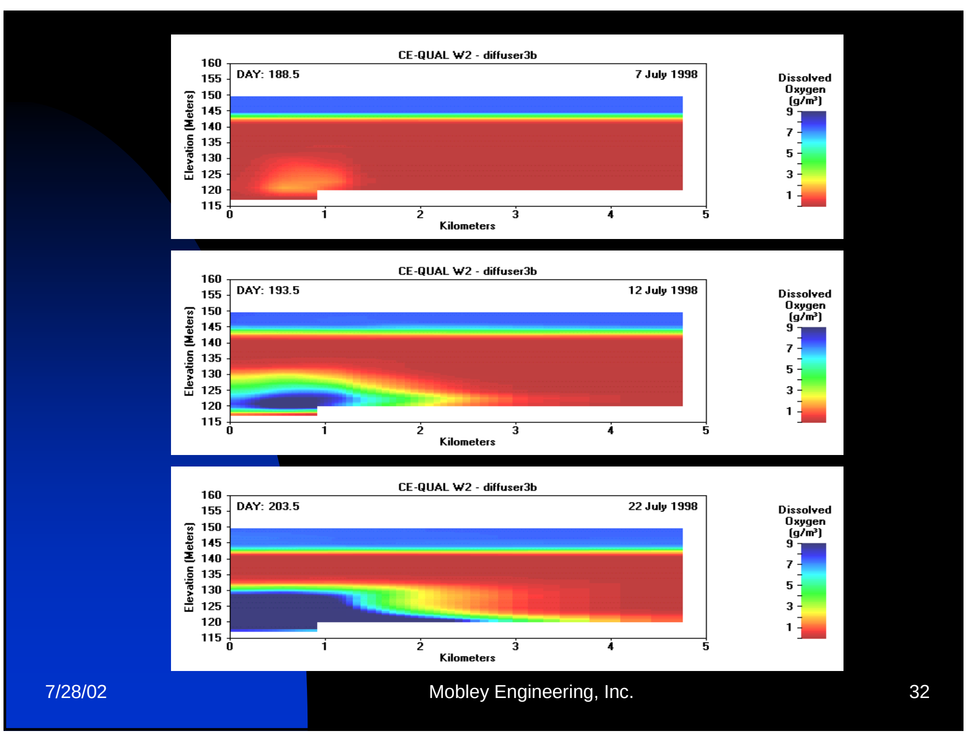


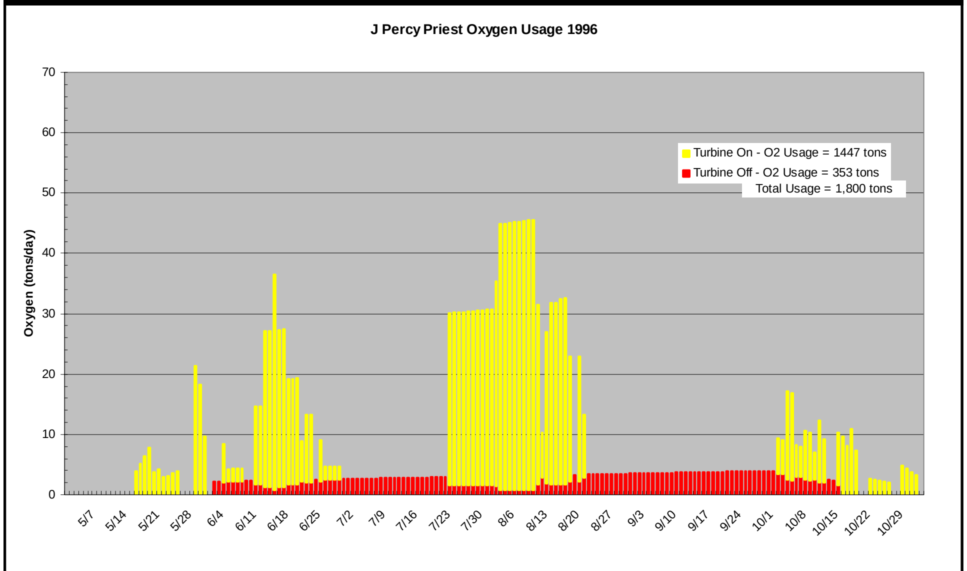
7/28/02 29

												WSE (meters)
												150
												149
												148
							O2 Input (Tons/day)		0.80	0.80		147
												146
								% Input	0.1	0.1		145
									0.1	0.1		144
									0.3	0.3		143
									0.5	0.5		142
									1	1		141
									2	2		140
									2	2		139
									4	4		138
									6	6		137
									8	8		136
									10	10		135
									12	12		134
									15	15		133
O2 Input (Tons/day)		0.30	0.30	0.30	0.30	0.24	0.18		18	18	Dam	132
									21	21		131
	% Input	0.1	0.1	0.1	0.1	0.1	0.1		Diffuser # 1			130
		0.2	0.2	0.2	0.2	0.2	0.2					129
		0.4	0.4	0.4	0.4	0.4	0.4					128
		1	1	1	1	1	1					127
		3	3	3	3	3	3					126
		5	5	5	5	5	5					125
		8	8	8	8	8	8					124
		10	10	10	10	10	10					123
		13	13	13	13	13	13					122
		16	16	16	16	16	16					121
		19	19	19	19	19	19					120
		23	23	23	23	23	23					119
				Diffuser # 3								118
												117
304.8	304.8	152.4	152.4	152.4	152.4	121.92	91.44	91.44	152.4	152.4	Cell Length (meters)	
1000	**1000**	**500**	**500**	**500**	**500**	**400**	**300**	**300**	**500**	**500**	Cell Length (feet)	

7/28/02 Mobley Engineering, Inc. 30


CE-QUAL W2 - diffuser1b
DAY: 193.5
12 July 1998
CE-QUAL W2 - diffuser1b
DAY: 198.5
17 July 1998
CE-QUAL W2 - diffuser1b
DAY: 203.5
22 July 1998
Elevation (Meters)
Kilometers
Dissolved Oxygen (g/m³)
7/28/02
Mobley Engineering, Inc.
31


CE-QUAL W2 - diffuser3b
DAY: 188.5
7 July 1998
CE-QUAL W2 - diffuser3b
DAY: 193.5
12 July 1998
CE-QUAL W2 - diffuser3b
DAY: 203.5
22 July 1998
Elevation (Meters)
Kilometers
Dissolved Oxygen (g/m³)
7/28/02
Mobley Engineering, Inc.
32



7/28/02 Mobley Engineering, Inc. 33

Costs $$$

- Estimated Costs for Oxygenation System at J Percy Priest:
  - Oxygen Supply Facility and Diffusers
    - 70 tons per day
    - 11,000 feet of diffuser
    - $1.0M to $1.2M capital costs
  - Operating Costs
    - 1,675 to 2,500 tons per year
    - $172,000 to $250,000

7/28/02 Mobley Engineering, Inc. 34